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FINAL PROGRESS REPORT

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This final summary report covers the five experiments that were conducted over a 24-month period beginning May 1, 1967 and ending April 30, 1969. Experiment I revealed that running and riding a bicycle ergometer produced similar gains in physical fitness variables. In Experiment II the subjects exercising at a 180 heart rate made a greater improvement in physical fitness than did those exercising at a 140 or 160 heart rate. In Experiment III, the subjects who exercised sixty minutes per day made greater gains on specified components of physical fitness than did those who exercised twenty or forty minutes per day. In Experiment IV, the subjects who exercised twelve times per week made greater gains on specified components of physical fitness than did those who exercised three or six times per week. In Experiment V, it was found that subjects could maintain a moderate level of fitness by exercising at a pulse rate of 160 beats per minute for twenty-minute periods three times per week, that subjects who "overtrained" by exercising twice daily to near exhaustion increased in fitness and that those subjects who discontinued training decreased in fitness.

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Methods of Achieving and Maintaining Physical Fitness for Prolonged Space Flight

A Summary of the Investigation of the Effects of the Kind of Activity, Work Load, Length of Training Sessions, Frequency of Training Sessions, Overtraining, Cessation of Training, and the Training Necessary to Maintain a Moderate Level of Physical Fitness in College Men

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I. Introduction

Prolonged weightlessness during space flight might result in deterioration of fundamental cardiovascular-respiratory responses. There has been considerable concern that prolonged space flights might cause cardiovascular deconditioning, making the space crewman susceptible to syncope or circulatory collapse during re-entry or return to earth (1). One of the principal problems encountered with prolonged weightlessness is the hypotension which develops upon return to gravity due to the loss of the cardiovascular reflexes. Another problem of great concern to space officials is that of space fatigue. Astronauts have found even mild extravehicular activity to be very exhausting.

Lamb (2) states that prolonged bed rest results in physiological deconditioning, manifested by decreased plasma volume, decreased red blood cell mass, decreased red blood cell production with inactive bone marrows, increased resting heart rate, decreased exercise tolerance, decreased orthostatic tolerance, decreased coronary blood flow, increased storage of catecholamine products in the myocardium, decreased muscle mass and muscle tonus, increased nitrogen excretion, and increased calcium mobilization with increased calcium excretion. Several methods have been suggested to overcome various aspects of this problem. These include pressure cuffs, a centrifuge, acclimatization, an antigravity suit and exercise devices. Due to the weight and space requirements in space vehicles none of these appear to approach an ideal solution. To prevent or at least to minimize this deconditioning during prolonged space flights, further research needs to be undertaken.

Miller and Taylor found that increased physical fitness decreased deconditioning during two or three weeks of absolute bed rest (3) (4). It is generally assumed that anything which decreases deconditioning during bed rest will also decrease deconditioning during prolonged space flights. With the appointment of physicians and scientists as astronauts for the long-term manned space flights which are being planned, research is needed in the area of developing and maintaining optimal physical fitness.

II. Purpose

The purpose of this investigation was to determine the kind of activity, work load, length of training sessions, and frequency of training sessions necessary to develop and maintain an optimal level of physical fitness. The effect of overtraining and cessation of training upon specified indexes of physical fitness was also investigated.

III. Method

Subjects used in this study were male college students who volunteered and had below average maximal oxygen uptake values as determined from the Balke Treadmill Test. (5) Baselines were determined on biochemical and physiological parameters by administering the following: (a) a medical examination, (b) a lean body mass determination, (c) an American Association for Health, Physical Education and Recreation (AAHPER) battery test, (d) a treadmill test, (e) a bicycle ergometer test, and (f) an orthostatic tolerance test.

Each subject had a thorough medical examination, including a six lead ECG, a vital capacity test, a maximum breathing capacity test, and blood and urine analysis. The subjects were given the Balke Treadmill Test in which the speed of the belt was constant throughout the test at 90 meters per minute with an increment in grade of 1% per minute. Pulse rate and blood pressure (systolic and diastolic) were measured manually at one minute intervals throughout the test. The pulse rate was also telemetered to a Cardio-Tac for continuous observation and the test was terminated when the heart rate reached 180 beats per minute. During the last minute of the treadmill test, pulmonary ventilation was measured and expired air collected to determine the respiratory quotient, maximum oxygen consumption, and oxygen uptake per kilogram of body weight.

Blood samples were obtained by venipuncture, with the subject in a fasting state, just prior to and immediately after the treadmill test. The following determinations were made: lactic acid by the enzymatic method of Loomis (6); glucose by the method of Nelson (7) and Somogyi (8); total cholesterol by the procedure of Babson, Shapiro, and Phillips (9); total protein by the method of Reinholt (10); phospholipids by the method of Sunderman (11); triglycerides by the method of Van Handel and Zilversmitt (12); urea nitrogen by the method of Conway (13); sodium, potassium, and calcium on the Coleman flame photometer; serum glutamic oxalacetic transaminase by the method of Babson, Shapiro, Williams, and Phillips (14); creatine phosphokinase by the Sigma method (15).

The subject's percent of body fat was determined by the body density method as described by Dill (16). An orthostatic tolerance test (17), the AAHPER Physical Fitness Test (18) and a bicycle ergometer test was given as part of the baseline evaluation.

The investigation was conducted in five phases designated as experiments. In each experiment there were four groups of five subjects each, who had been assigned to groups by a table of random numbers. The training period in each experiment lasted ten weeks.

At the end of every two experimental weeks of training the physical capacity of each subject was assessed by administering the bicycle ergometer test as follows. The subject exercised for three minutes at 300 kilopond meters per minute. At the beginning of each minute thereafter, the workload was increased by 75 kpm. When the heart rate reached 180 beats per minute the test was terminated. Gas samples were collected during the third, fifth, eighth, and each of the last three minutes of exercise to obtain oxygen consumption data. The heart rate, blood pressure, and respiration rate were measured each minute of the test as well as three minutes pre-test and three minutes post-test.

At the end of the ten weeks each subject's physical fitness was again evaluated to determine the effectiveness of the different training programs. Indexes of physical fitness which were investigated included resting heart rate, blood volume, plasma volume, red blood cell volume, red blood cell production, exercise tolerance, orthostatic tolerance, lean body mass, maximal oxygen consumption, maximal oxygen uptake per kilogram of body weight, and the AAHPER scores. Blood volume, plasma volume and red blood cell volume were determined by injection of Evans Blue according to a procedure outlined by General Diagnostic Division of the Warner-Chilcott Co. Measurements were made on several biochemical and physiological parameters to determine the nature and extent of any change which took place as a result of the physical training.

The activities of each training group are described below under its respective experiment and this information is then summarized in Table I. In each experiment Group D served as the control group and engaged in their normal daily schedule without participating in an exercise program.

Experiment I

The three exercise groups followed a prescribed training program of twenty minutes per day, five days per week, for ten weeks. The daily training period consisted of a five-minute warmup with the work load adjusted to produce a heart rate of 120-130 beats per minute, followed immediately by fifteen minutes of exercise with the work load adjusted to produce a heart rate of 160 beats per minute.

Group A exercised on a Monarch Bicycle Ergometer with the work load adjusted each minute to produce the desired heart rate for the warmup and the exercise periods. Group B jogged for five minutes and then ran for fifteen minutes at a speed required to maintain a heart rate of 160 beats per minute. The pulse rate was determined every half mile. Group C exercised on a treadmill by walking at a constant speed of 90 meters per minute with the elevation of the mill being adjusted each minute to produce the desired heart rate. A reasearch assistant checked the heart rate during exercise and adjusted the work load to bring about the desired heart rate.

Experiment II

The three exercise groups followed a prescribed training program on a bicycle ergometer twenty minutes per day, five days per week, for ten weeks. The daily training period consisted of a five-minute warmup with the work load adjusted to produce a heart rate of 120-130 beats per minute, followed immediately by fifteen minutes of exercise with the work load adjusted to produce a different heart rate for each group.

Group A exercised with the work load adjusted to produce a heart rate of 140 beats per minute. Group B exercised at a heart rate of 160 beats per minute, and Group C exercised at a heart rate of 180 beats per minute. A research assistant checked the heart rate each minute during exercise and adjusted the work load when necessary to maintain the desired heart rate.

Experiment III

The three exercise groups followed a prescribed training program on a bicycle ergometer five days a week for ten weeks. The daily training period consisted of a five-minute warmup with the work load adjusted to produce a heart rate of 120-130 beats per minute, followed immediately by a work load adjustment to produce a heart rate of 180 beats per minute for each group.

Group A exercised for twenty minutes per day, Group B forty minutes per day, and Group C sixty minutes per day. A research assistant checked the heart rate each minute during exercise and adjusted the work load when necessary to maintain the desired heart rate.

Experiment IV

The three exercise groups followed a prescribed training program on a bicycle ergometer for ten weeks. The training period consisted of a five-minute warmup with the work load adjusted to produce a heart rate of 120-130 beats per minute, followed immediately by a work load adjustment to produce a heart rate of 160 beats per minute which, for each group, was maintained for fifteen additional minutes. Group A exercised three times per week, Group B six times per week, and Group C twelve times per week. A research assistant checked the heart rate each minute during exercise and adjusted the work load when necessary to maintain the desired heart rate.

Experiment V

The fifteen subjects who were to be assigned to treatment groups were brought to an average level of physical fitness by an individualized training program. Subjects were then assigned by use of a table of random numbers to three groups of five individuals per group.

Group A exercised on a bicycle ergometer sufficiently to maintain their level of physical fitness. It was determined from the semimonthly bicycle tests described on page four that three training periods per week of twenty minutes per period were sufficient to maintain a moderate level of fitness. A more strenuous training program would be required to maintain a high level of fitness. During these exercise periods the pulse rate of the subject was brought to 160 beats per minute and maintained at that level for the remainder of the period by a research assistant who checked the pulse rate each minute and made the necessary adjustment in the work load.

Group B "overtrained" by exercising two times per day, five days per week in the following manner. The subject exercised for one minute at 150 kilopond meters per minute. At the beginning of each minute thereafter the work load was increased 150 kpm until the subject was unable to maintain the specified pedalling rate of 50 rpm. The complete cycle was then repeated so that each subject was worked to near exhaustion twice in each exercise period for a total of four times per day. This resulted in an average of forty-nine minutes of work per day.

After three weeks the training program was changed primarily for psychological reasons. The subject worked the first minute at 300 kpm and at the beginning of each minute thereafter the workload was increased 300 kpm until the subject could no longer maintain the pedalling rate of 50 rpm. The workload was then reduced 300 kpm each minute until a load of 300 kpm per minute was reached. This cycle was then repeated with the entire exercise being repeated during an afternoon workout. This resulted in an average of forty-five minutes of work per day.

Group C stopped all training and reverted to their normal daily activities.

Table I summarizes the above information concerning training groups and their treatment.

TABLE I

THE TRAINING GROUPS AND THEIR ACTIVITIES IN EACH EXPERIMENT*

EXPERIMENT	VARIABLE	GROUPS**			
		A	B	C	D
I	Activity	Bicycling	Running	Treadmill Walking	Control
II	Work Load (Pulse rate in beats/min)	140	160	180	Control
III	Training Session Length (min)	20	40	60	Control
IV	Training Session Frequency (Times/week)	3	6	12	Control
V	Post-Training Discipline	Maintain	Overtrain	Quit Exercising	Control

*Hereafter, the groups will be referred to by the experiment number and group letter. For example, Group C in Experiment II will be designated Group II-C.

**In previous progress reports, groups have been designated by Roman numeral rather than by capital letter.

IV. Results

The variables that were measured and whose mean pre-training, post-training and difference values have been reported in the previous progress reports are listed in Table II. Prior to the beginning of each experiment, the decision was made to make comparisons between the first and last tests for each group. The data were statistically treated by the analysis of variance and details concerning the statistical analyses were given in previous progress reports.

TABLE II
VARIABLES WHICH WERE MEASURED

AAHPER TEST ITEMS

1. Pullups
2. Situps
3. Shuttle Run
4. Standing Broad Jump
5. 50-Yard Dash
6. Softball Throw
7. 600-Yard Run
8. Mean AAHPER Percentile

PHYSIOLOGICAL VARIABLES

9. Weight
10. Percent Body Fat
11. Hemoglobin
12. Hematocrit
13. Red Blood Cells
14. Reticulocytes
15. Red Blood Cell Volume
16. Plasma Volume
17. Total Blood Volume

TREADMILL TEST VARIABLES

18. Time on Treadmill to 180 Pulse Rate
19. Vital Capacity
20. Maximum Breathing Capacity (MBC)
21. Respiratory Rate During MBC Test
22. Tidal Volume During MBC Test
23. Maximal Pulmonary Ventilation ($\dot{V}_E$) at Body Temperature Pressure Saturated (BTPS)
24. Respiratory Rate at $\dot{V}_E$
25. Tidal Volume at $\dot{V}_E$
26. Carbon Dioxide (CO_2) Produced at $\dot{V}_E$
27. Oxygen (O_2) Uptake at $\dot{V}_E$
28. O_2 Uptake/Pulse at $\dot{V}_E$
29. O_2 Uptake/kg body weight·min (kgbw·min) at $\dot{V}_E$
30. $\dot{V}_E/O_2$ Uptake

TABLE II VARIABLES WHICH WERE MEASURED.............Continued

31. Respiratory Quotient at $\dot{V}_E$

32. Systolic Blood Pressure at Rest

33. Systolic Blood Pressure at 180 Pulse Rate

34. Diastolic Blood Pressure at Rest

35. Diastolic Blood Pressure at 180 Pulse Rate

36. Pulse Rate at Rest

37. Pulse Rate at Last Minute of Work

SERUM DETERMINATIONS (Before*)

38. Glucose

39. Glutamate Oxaloacetate Transaminase (SGOT)

40. Total Cholesterol

41. Phospholipids

42. Sodium

43. Potassium

44. Total Protein

45. Creatine Phosphokinase

46. Urea Nitrogen

47. Calcium

48. Triglycerides

49. Lactic Acid

SERUM DETERMINATIONS (After**)

50. Glucose

51. Glutamate Oxaloacetate Transaminase (SGOT)

52. Total Cholesterol

53. Phospholipids

54. Sodium

55. Potassium

56. Total Protein

57. Creatine Phosphokinase

58. Urea Nitrogen

59. Calcium

60. Triglycerides

61. Lactic Acid

BICYCLE TEST VARIABLES

62. Time on Bicycle to 180 Pulse Rate

63. Pulmonary Ventilation at 8th Minute at BTPS

64. $\dot{V}_E$ at BTPS

65. Respiratory Rate at 8th Minute

66. Respiratory Rate at $\dot{V}_E$

67. Tidal Volume at 8th Minute

68. Tidal Volume at $\dot{V}_E$

69. CO_2 Produced at 8th Minute

70. CO_2 Produced at $\dot{V}_E$

71. O_2 Uptake at 8th Minute

72. O_2 Uptake at $\dot{V}_E$

73. O_2 Uptake/Pulse at 8th Minute

74. O_2 Uptake/Pulse at $\dot{V}_E$

75. O_2 Uptake/kgbw•min at 8th Minute

76. O_2 Uptake/kgbw•min at $\dot{V}_E$

77. Pulmonary Ventilation/O_2 Uptake at 8th Minute

78. $\dot{V}_E/O_2$ Uptake

79. Respiratory Quotient at 8th Minute

TABLE II VARIABLES WHICH WERE MEASURED............Continued

80. Respiratory Quotient at $\dot{V}_E$	85. Pulse Rate at Rest
81. Systolic Blood Pressure at Rest	86. Pulse Rate at Last Minute of Work
82. Systolic Blood Pressure at 180 Pulse Rate	87. Systolic Blood Pressure at 3rd Minute of Recovery
83. Diastolic Blood Pressure at Rest	88. Diastolic Blood Pressure at 3rd Minute of Recovery
84. Diastolic Blood Pressure at 180 Pulse Rate	89. Pulse Rate at 3rd Minute of Recovery

*Comparison of the resting, fasting, pre-training values with the resting, fasting, post-training values.

**Comparison of the post-treadmill test, fasting, pre-training values with the post-treadmill test, fasting, post-training values.

The significant changes that were found are presented in Table III. The variables are designated by number in the sequence presented in Table II and an explanation of the symbols that are used for groups is found in Table I. If a significant decrease was found, this is indicated by a minus sign placed in front of the level of significance. A significant increase is indicated by the lack of any sign before the significance level.

From Table III, it appears that the change in total work performed until a pulse rate of 180 beats per minute is reached (variables 18 and 62) is the best indicator of an increase or decrease in physical fitness. The change in carbon dioxide produced and oxygen consumed at maximal pulmonary ventilation (variables 26, 27, 28, 29, 70, 72, 74, and 76) are also very good indicators of an increase or decrease in physical fitness.

TABLE III

THE DIRECTION AND SIGNIFICANCE LEVEL OF CHANGES
IN MEASURED VARIABLES AMONG TRAINING GROUPS

GROUPS* / VARIABLES**	I-A	I-B	I-C	I-D	II-A	II-B	II-C	II-D	III-A	III-B	III-C	III-D	IV-A	IV-B	IV-C	IV-D	V-A	V-B	V-C	V-D
1	.05																			
2							.01				.01			.01			.05	.05		
3																.001			.05	
4				-.05										-.05						
5		.01				-.01		-.05				.05					.01		.05	.01
6		-.01															.001	.001	.001	
7				.05				-.05	-.05						-.05	.05	-.05	-.05		
8				-.05												-.01		.05	-.05	
9	-.01	-.01			-.01		-.01							.001			-.05	-.01		
10																				.01
11																	-.05	-.01		
12		-.05																		
13											.05			.05		.05				
14	-.05								-.05											
15											-.05									
16			.05			-.05					-.01									
17											-.01									
18	.001	.001	.001		.001	.001	.001		.001	.001	.001		.05	.05	.001			.05		
19																	.05			
20							.01	.01												
21							.01			.05							-.05			
22										-.05	-.05						.05			
23		.01			.05	.01	.01		.01	.001	.01		.01	.05	.001			.05		
24						.01			.05	.05	.01		.01		.001					
25		.05				-.05	.05			.05										
26	.01	.001					.05		.01	.001	.001		.01	.05	.001					
27	.05	.01					.01		.001	.001	.001		.01	.05	.001	.05		.05		
28	.05	.01					.001		.001	.001	.001		.01	.05	.001	.05		.05		
29	.01	.001			.05		.01		.01	.001	.001		.001	.05	.001	.05		.05		
30						.05														
31		.01								.05						-.05				
32	-.05	-.01		-.05																
33										.01	.01			.001					-.05	

*See Table I
**See Table II

TABLE III.....THE DIRECTION AND SIGNIFICANCE LEVEL OF CHANGES IN MEASURED VARIABLES AMONG TRAINING GROUPS....Continued

GROUPS* / VARIABLES**	I-A	I-B	I-C	I-D	II-A	II-B	II-C	II-D	III-A	III-B	III-C	III-D	IV-A	IV-B	IV-C	IV-D	V-A	V-B	V-C	V-D
34												-.05	.001			.01			.05	
35		-.01			-.01		-.05		-.001	-.05	-.001	-.01								
36	-.01	-.05				-.001			-.05	-.001	-.05									.001
37							-.01									-.05				
38	-.001	-.01	-.01	-.05	-.05															
39			.01							-.05				.001	.001	.001				.01
40									.05											
41																				-.05
42	-.05			-.01						.01	.01	.01		.01			-.05			
43					-.05											.01	-.05	-.01		
44	-.001	-.001	-.001	-.05	-.01	-.01	-.05	-.01		.05		.001		-.05						-.05
45							.05													
46						-.05													.01	
47			-.001	-.001				.01	-.001	-.001	-.001	-.001	-.05	-.01		-.05		-.05		
48				.01														-.05		-.01
49		-.01															-.05			
50	-.01			-.05	-.05								-.01		-.05				-.001	
51	.05	.01	.001	.01		-.05								.001	.001	.001	.01	.05	.01	.001
52																				
53			.05						.01										.05	
54										.05	.01	.001								.05
55					-.05						.01		.01			.001				
56	-.001	-.05	-.01			-.05	-.05	-.01		.01		.001								
57																				
58						-.05													.01	
59			-.05					.001	-.001	-.001	-.001	-.001	-.001	-.05		-.05	-.01			
60				.01														-.05		-.001
61								.05		.05										.05
62	.001	.001	.001	.001	.001	.001	.001		.001	.001	.001		.001	.001	.001			.001	-.001	
63	-.001				-.001	-.001	-.001	-.05	-.05		-.05									
64	.01	.001		.05							.05		.01		.01	.05		.01		
65	-.001								-.05											
66		.05							-.05						-.01					.05
67		.05			-.05	-.05	-.01	-.01												
68	.001	.001	.01	.05			.05		.01	.05			.05		.001	.05				
69	-.01				-.001	-.001	.001	-.001			-.01									

*See Table I

**See Table II

TABLE III.....THE DIRECTION AND SIGNIFICANCE LEVEL OF CHANGES IN MEASURED VARIABLES AMONG TRAINING GROUPS....Continued

GROUPS* / VARIABLES**	I-A	I-B	I-C	I-D	II-A	II-B	II-C	II-D	III-A	III-B	III-C	III-D	IV-A	IV-B	IV-C	IV-D	V-A	V-B	V-C	V-D
70	.001	.001			.01		.001		.01	.01	.001	.05	.001	.05	.01	.05		.05	-.01	
71					-.01	-.001	-.001	-.01												.05
72	.001	.001	.05		.01	.05	.001		.001	.01	.001		.001	.01	.001	.01		.01	-.05	
73									.05		.001								-.01	.05
74	.01	.01			.01		.001		.001	.01	.001		.001	.01	.001	.05		.01	-.05	
75						-.01	-.01	-.01												
76	.001	.001			.01		.001		.001	.01	.001	.05	.001	.05	.001	.05		.001	-.05	
77	-.05				-.001						-.05									
78		.05				-.01			-.01		-.05			-.05						
79	-.05				-.001		-.01				-.001				-.001	-.05				
80																				
81						-.01	-.01													
82																				
83			-.05	-.05														.05		
84			-.01			-.001	-.05		-.001		-.01	-.05		-.01			-.05		.05	
85				-.01	-.01						-.05						.05			
86	.01		.05					-.05												
87																				
88			-.05	-.01														.01		
89										-.05	-.001									

*See Table I

**See Table II

Table IV lists the variables in which a significant increase indicates a gain in physical fitness. Conversely, a significant decrease in these variables would indicate a loss in fitness. The significant increases and decreases in these variables are found in Table III except for Variable 90. For Variable 90, there was a significant increase in Group III-B at the .05 level and a significant increase in Group III-C at the .001 level.

TABLE IV

VARIABLES IN WHICH A SIGNIFICANT INCREASE INDICATES A GAIN IN PHYSICAL FITNESS AND A SIGNIFICANT DECREASE INDICATES A LOSS IN PHYSICAL FITNESS

NUMBER*	VARIABLE	NUMBER*	VARIABLE
1	Pullups	25	Tidal Volume at $\dot{V}_E$ (TM)
2	Situps	26	CO_2 Produced at $\dot{V}_E$ (TM)
4	Standing Broad Jump	27	O_2 Uptake at $\dot{V}_E$ (TM)
6	Softball Throw	28	O_2 Uptake/Pulse at $\dot{V}_E$ (TM)
8	Mean AAHPER Percentile	29	O_2 Uptake/kgbw·min. at $\dot{V}_E$ (TM)
11	Hemoglobin	61	Lactic Acid (After)
12	Hematocrit	62	Time on Bicycle to 180 Pulse Rate
13	Red Blood Cells	64	$\dot{V}_E$ at BTPS (Bike)
14	Reticulocytes	68	Tidal Volume at $\dot{V}_E$ (Bike)
15	Red Cell Volume	70	CO_2 Produced at $\dot{V}_E$ (Bike)
16	Plasma Volume	72	O_2 Uptake at $\dot{V}_E$ (Bike)
17	Total Blood Volume	73	O_2 Uptake/Pulse at 8th Min.(Bike)
18	Time on Treadmill to 180 Pulse Rate	74	O_2 Uptake/Pulse at $\dot{V}_E$ (Bike)
19	Vital Capacity	76	O_2 Uptake/kgbw·min. at $\dot{V}_E$(Bike)
20	Maximum Breathing Capacity	90	Variable 86 minus Variable 89
23	$\dot{V}_E$ at BTPS (TM)		

*See Table II

The variables in which a significant decrease indicates a gain in physical fitness are presented in Table V. Conversely, a significant increase in these variables indicates a loss of fitness. The significant increases and decreases in these variables are found in Table III.

TABLE V

VARIABLES IN WHICH A SIGNIFICANT DECREASE
INDICATES A GAIN IN PHYSICAL FITNESS AND A SIGNIFICANT
INCREASE INDICATES A LOSS IN PHYSICAL FITNESS

NUMBER*	VARIABLE	NUMBER*	VARIABLE
3	Shuttle Run	48	Triglycerides (Before)
5	50-Yard Dash	63	Pulmonary Ventilation at 8th Min. at BTPS (Bike)
7	600-Yard Run	67	Tidal Volume at 8th Min. (Bike)
9	Weight	69	CO_2 Produced at 8th Min. (Bike)
10	Percent Body Fat	71	O_2 Uptake at 8th Min. (Bike)
30	$\dot{V}_E/O_2$ Uptake (TM)	75	O_2 Uptake/kgbw•min. at 8th Min. (Bike)
33	Systolic Blood Pressure at 180 Pulse Rate (TM)	77	Pulmonary Ventilation/O_2 Uptake at 8th Min. (Bike)
35	Diastolic Blood Pressure at 180 Pulse Rate (TM)	78	$\dot{V}_E/O_2$ Uptake (Bike)
36	Pulse Rate at Rest (TM)	82	Systolic Blood Pressure at 180 Pulse Rate (Bike)
40	Total Cholesterol (Before)	84	Diastolic Blood Pressure at 180 Pulse Rate (Bike)
41	Phospholipids (Before)	85	Pulse Rate at Rest (Bike)

*See Table II

The total number of significant changes which indicate a gain or a loss in physical fitness is presented by groups in Table VI. The gains are the total significant increases in Table III for the selected variables of Table IV plus the total significant decreases in Table III for the selected variables of Table V. Conversely, the losses are the total significant decreases in Table III for the selected variables of Table IV plus the total significant increases in Table III for the selected variables of Table V. The net gain which is tabulated in the third column under Difference is the number of significant changes indicating a gain in physical fitness minus the number of significant changes indicating a loss in fitness.

TABLE VI

THE NUMBER OF SIGNIFICANT CHANGES IN
VARIABLES WHICH INDICATE A GAIN OR LOSS
IN PHYSICAL FITNESS AMONG GROUPS

EXPERIMENT	GROUP	GAIN*	LOSS**	DIFFERENCE***
I	A	18*****	1	17
	B	17*****	5	12
	C	6*****	0	6
	D	3	4	-1
II	A	16****	0	16
	B	13	3	10
	C	23	0	23
	D	9	0	9
III	A	19	2	17
	B	17	2	15
	C	24****	4	20
	D	4	1	3
IV	A	13	0	13
	B	15	3	12
	C	14	0	14
	D	10	3	7
V	A	6*****	3****	3
	B	17	1	16
	C	2	10	-8
	D	4	4	0

*The total number of significant increases in the variables in Table IV plus the total number of significant decreases in the variables in Table V.

**The total number of significant decreases in the variables in Table IV plus the total number of significant increases in the variables in Table V.

***Gain minus loss.

****The discrepancy that exists between this figure and that given in previous progress reports is due to the addition of Variable 85 to Table V.

*****The discrepancy that exists between this figure and that given in previous progress reports is due to error in previous reporting of data.

The measurement of maximal oxygen consumption per kilogram of body weight is one of the most common physiological methods of assessing physical fitness. This is an important measure of the cardiovascular-respiratory system to meet the demands placed on it by continued vigorous physical activity (19). Not only is the maximal oxygen uptake the best single physiological indicator of the capacity of a man for sustaining hard work, it is also the most objective measure by which insight is gained into the physical fitness of an individual as reflected by his cardiovascular system (20). Newton found the Balke Treadmill Test to be one of the better instruments for determining maximal oxygen consumption (21).

The Balke Treadmill Test and the bicycle ergometer test described on page four of this report were both used to measure oxygen uptake at a 180 pulse rate, pre and post training, in these experiments. The values obtained from the treadmill and the bike tests were combined and the percent of change values for each group in each experiment are presented in Table VII.

TABLE VII

THE PERCENT OF CHANGE IN OXYGEN PER KILOGRAM OF BODY WEIGHT VALUES

	GROUPS			
Experiment*	A	B	C	D
I	19.8	22.9	8.5	7.6
II	18.6	11.0	25.1	-6.7
III	21.0	21.2	25.7	6.6
VI	31.4	19.4	32.4	17.6**
V	-2.4	13.1	-4.4	-1.4

*See Table I.

**This increase was largely due to one of the control subjects training for and engaging in spelunking. This was unknown until the experiment was completed.

V. Summary

There are some slight discrepancies, as indicated in the footnotes, between some of the values in Table VI and values which were previously reported. These do not materially affect the conclusions which have been reported and are further substantiated by the data presented in Table VII. In Experiment I, the running group and the group exercising on the bicycle made similar gains in fitness. In Experiment II, the group exercising at a pulse rate of 180 beats per minute made the greatest gain in fitness. In Experiment III, the group exercising for sixty minutes per training session made the greatest gain in fitness. In Experiment IV, those subjects exercising twelve times per week made the greatest gain in physical fitness. In Experiment V, subjects were maintained at a moderate level of fitness by exercising at a pulse rate of 160 beats per minute for twenty-minute periods three times per week. Subjects who were "overtrained" by exercising twice daily to near exhaustion gained in fitness while those subjects who discontinued exercising decreased in fitness.

VI. Recommendations

The single variable which is most readily measured quantitatively and probably best indicates the level of physical fitness is maximal oxygen uptake per kilogram of body weight per minute. Our data would indicate that a person in good physical condition should be able to consume 40-45 ml of O_2/kgbw·min. at 180 pulse rate. Because of the great expense and effort that has been put into the Apollo program, the physical work which the astronauts will be increasingly called upon to perform for extended periods of time and the possible exigencies which they might encounter on a space flight, a good level of fitness should be a minimum requirement for all astronauts. We feel that it would be best if the astronauts could consume at least 45 ml of O_2/kgbw·min., but that 40 ml be the absolute minimum.

Our investigation indicates that a person could reach a good level of physical fitness by exercising at a pulse rate of 160 beats per minute for twenty-minute periods five times a week. We recommend that all who aspire to space flight be required to obtain this minimum amount of exercise. To achieve a high level of fitness, an astronaut should exercise at a pulse rate above 160 beats per minute for thirty-minute periods five times a week. The pulse rate during exercise that is recommended is contingent upon a maximal pulse rate of approximately 180-190 beats per minute. It has been our experience that a few individuals have a maximal pulse rate that is appreciably higher than 190 beats per minute. In such individuals, a pulse rate of 160 beats per minute during exercise might not be sufficient to produce a good level of fitness. Such individuals would have to exercise at a higher pulse rate.

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